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SELECTION THE OPTIMAL PARAMETERS OF DRILLING AND BLASTING OPERATIONS AT THE OPEN PIT OF STONE COAL "PROGORELICA" - BALJEVAC

Abstract

Blasting is an integral part of excavation in the field "Progorelica". The quality of blasted material depends on proper selection of drilling and blasting operations, why the arrangement of boreholes and quantity of explosives need to be determined so that the effect of explosion is in the range r/W <0.75, i.e. without creating a large explosion funnel, but rather weakening it.

Keywords: *blasting, borehole, explosive, explosion funnel*

1 INTRODUCTION

Blasting is a part of overburden excavation technology in the field "Progorelica" in the areas where it is needed, i.e. in the working environments with physical and mechanical properties such as that the digging resistance is greater than the cutting force of Dragline M-7200 excavator. The purpose of mining the overburden is not as with the loading by hydraulic excavator complete separation of the block for loading from the whole, but only the distortion of cohesion between the particles in order to reduce the resistance during the excavation of waste rock. If during blasting the line of least resistance would be less than the radius of the base of explosion funnel (w <r), or if it would be equal to it (w=r) the material of blasted block would separate from the rock mass and found beyond the reach of the excavator M-7200. This effect of explosion is undesirable, there at in the arrangement of blasting holes and determination of the amount of explosive in them it needs to be strictly kept in mind that these are so determined that the effect of explosion re mains within the limits r/W <0.75 i.e. that the visible explosion funnel does not form, but rather weakened. It should be noted that the needs for blasting increase with increasing hardness of overlying sediments, because the excavator M-7200 could successfully excavate the overburden in the filed "Progorelica" even without the use of explosives, if the hardness of the material would be such that the resulting digging resistance is lower than the size of excavator cutting forces and if one would not pursue the minimum level of inclination of 60°. However, as it can be seen from the results of testing hardness of overlying sediments and interlayer waste that variable is the same and ranges from 1.37-1.88 for the soft sandstone and from 5.57-6.87 for moderately hard marl or marly limestone, so that excavation of harder lots without use of explosives would be impossible and also without disrupting the cohesion between the particles, especially in the foot wall section and in cutting the block. Applying the table of Novo-zhylova calculating the specific

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consumption of explosives in such a mode, the value obtained exceeds several times the values of experiential results, so that it is not practically applicable. Therefore, it is most secure that in determining the amount of explosive and arrangement of blasting holes to comply with the parameters that in the field Tadenje have already shown the results of mining and a trial mining is performed in the field "Progorelica" [1].

2 DRILLING AND BLASTING OPERATIONS

For performing drilling and blasting operations and for the purpose of destruction or shaking the working environment, the mine disposes with a self-propelled drill rig SVG-730 with a rotary hammer for mining and construction equipment in manufacturing RK-26MI.

Drilling carriage SHG-730 with deep hammer RK-26MI is intended for drilling diameters of 80 – 105 mm. Drilling rate ranges from 4-12 m/h, depending on the material, other mountaingeological conditions, proper maintenance and on several factors of technical and organizational character. The soft material can also be drilled (rotary drilling), such as for example, clay, earth and taking the core.

Drilling possibility

1. Horizontally up to a height	from 250 - 1800 mm
2. Vertically	up to + cca 27^0
3. Laterally	to 72^0

Determination of drilling parameters

The basic available information and of influence on the adoption of parameters of drilling - blasting works are:

Height level	H = 10m
Angle of inclinable level	$\alpha = 60^o$
Volumetric mass	$\gamma = 2230$ kg/m^3
Maximum diameter of blasted piece	$l_d = 700$ mm

Height of blasted level

By vertical division of deposits the height of level is determined where dragline excavator will operate and it is up to 10m with an inclination of operation slopes of α = 60°. At opening the first level, the height will change until it reaches 10m and, in that case, different depths of boreholes will be in blasting. During opening the I level, there will not be two free surfaces and thus the arrangement of blast boreholes and quantity of explosives in them will be different than in a regular technology. Figure 1 shows the arrangement of blast boreholes in cramped conditions (straitened minefield) needed for faster bringing into regular blasting technology.

As it can be seen from Figure 1, the block which will be opened needs to be drilled chequerwise in 5 rows across the width of block (labeled 1 through 5) and 6 per depth of block (labeled from a to f).

The arrangement of boreholes is provided on the spot as well as a way of charging them by person responsible for carrying out drilling and blasting operation depending on the material and the relief of terrain where they are performed. Distance between the boreholes is equal to

5 m, but the depth of boreholes and the amount of explosives in them is not the same (Figure 2). Depth of boreholes can be seen in profile A-A per depth of the block.

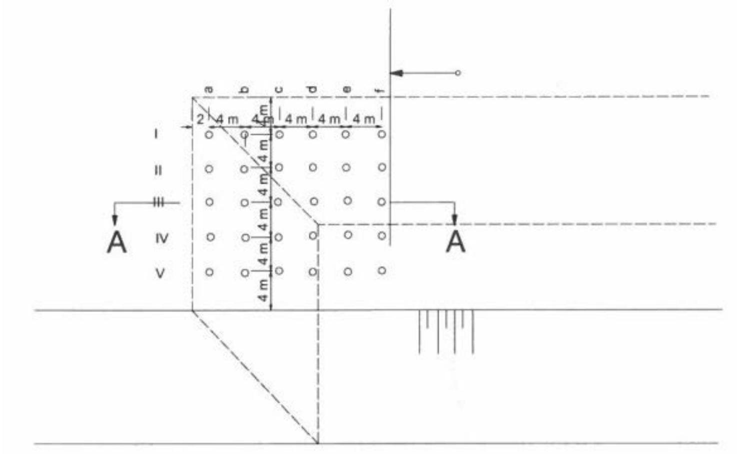

Figure 1 *Arrangement of blast boreholes in cramped conditions (straitened minefield)*

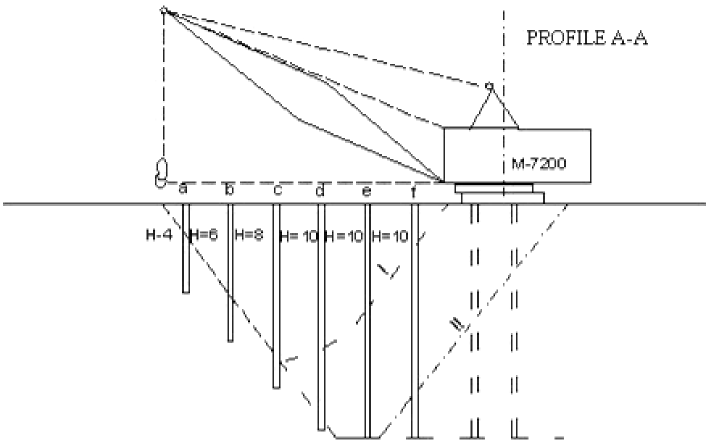

Figure 2 *Height of borehole in opening cutting*

The basic rule is that the blockage at the top of borehole needs to be at least:

- For boreholes up to 5 m depths - at least one half of the borehole depth
- For boreholes up to 6 to 10 m - at least one third of the borehole depth

Detailed instructions are provided by the technical manager through safety service at work.

Inclination angle of borehole

In calculating the inclination of operation slopes, the inclination angle of $\alpha = 60^o$ is adopted. In order to ensure the required security and stability of levels, the adopted boreholes inclination is the same as in operation inclination: $\alpha = 60°$. The same boreholes inclination is also adopted in the variant of opening the level.

Borehole depth

Total length of the borehole depends on:

- Level height (H)
- Borehole inclination (α)
- Pitting size (l_{pr})

The general formula for calculation the blasting hole depth has the form:

$L_b = H/\sin\alpha + l_{pr}$;

where:

L_b - total length of blasting borehole
H - level height (10 m)
l_{pr} - pitting below the floor level
α - inclination angle of borehole (60°)

$l_{pr} = (0.15 – 0.30)$ w

$l_{pr} = 0.2 \cdot 4.0$

$l_{pr} = 0.8$ m

$L_b = 10/\sin60^o + 0.8$

$L_b = 12.4$ m

3 DRILLING DIAMETER

Drilling diameter is directly linked with the choice of excavator or excavator bucket capacity. Starting from the overall dimensions (>0.75 $\sqrt[3]{qk}$) through the formula:

$$d = \frac{70}{\sqrt{P_{ex}}} \cdot q_k^{\ 0,165} \cdot \sqrt{\eta_1 k_1 \cdot q^{0,1}}$$

where:

q_k - excavator bucket capacity 5,.

$\eta_1 = \frac{W}{H}$ - ratio of the line of least resistance and height levels

k_1 - coefficient of proportionality

q - specific consumption of explosive kg/m^3

P_{ex} - power coefficient of explosive

adopted as: d = 0,088 m

4 THE LEAST RESISTANCE LINE

By definition, the least resistance line is the shortest distance from the center of placement of explosive charge in the borehole to free surface. With inclined boreholes, it is equal to length of the entire borehole. The value of this parameter depends on: physical- mechanical and structural characteristics of the working environment, power and quantity of explosive charge and distribution of boreholes. There are several formulae for determining the least resistance line, and in principle formulae should be used that contain a larger number of dependent values.

The least resistance line is usually calculated according to the formula:

$$w = 53 \cdot kr \cdot d \cdot \sqrt{\frac{\gamma_e}{\gamma}}$$

where:

w - line of least resistance
kr - fissure coefficient 1.25
d - borehole diameter 88 mm
γ_e - volumetric mass of explosive 1.05 g/cm^3
γ - volumetric mass of the area being shaken 2.23 g/cm^3

$$w = 53 \cdot 1.25 \cdot 0.88 \cdot \sqrt{\frac{1.05}{2.23}}$$

adopted as w = 4.0 m

After determining the optimal length of the least resistance line w, it is preceded to the experimental blasting with varying distances between the boreholes to determine the coefficient of overlapping (density).

5 DISTANCE BETWEEN THE BOREHOLES IN A ROW

This parameter of drilling and blasting operation is determined by the size of the least resistance line:

$a = m \cdot w \cdot (m)$

where:

m - coefficient of rapprochement of boreholes in a row a - distance between the boreholes in a row (m)

$a = 1.1 \cdot 4\ m = 4.4\ m$

adopted as: a = 5 m

6 DISTANCE BETWEEN THE ROWS OF BOREHOLES

The effect of blasting at the open pits largely depends on the arrangement of boreholes. The holes in rows are distributed to form a square, rectangular or triangular arrangement. In cases where the blast holes are parallel to the slope of level (inclined), the distance between the rows of holes (b) is usually equal to the size of the line of least resistance:

$b = w$

where:

b - distance between the rows of boreholes (m)

w - line of least resistance (m adopted as: b = 4.0 m

The arrangement of boreholes is shown in the following Figure:

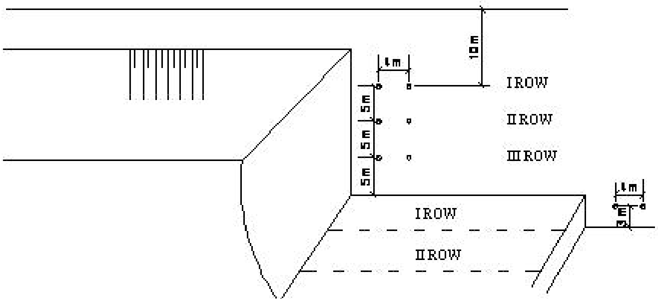

Figure 3 *The arrangement of blast boreholes*

As shown in Figure 3, row III of boreholes falls on the foot of the level slope, and that is why although there are two free surfaces, explosive is placed in it, because the excavator in cutting the floors has the worst conditions (bucket freefall) precisely at the profile line coinciding with the third row of blast boreholes. Slope of the level is already shot off in the earlier mining of the previous block (I and II row of boreholes is shown with dotted lines in Figure 3).

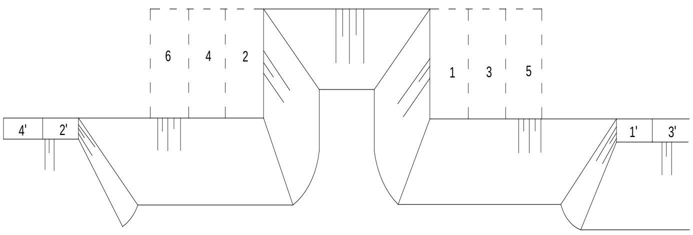

Figure 4 *The order of blasting the floor with excavation from the middle to the wings of floor*

The auxiliary block should ensure the coal production in one shift where blasting takes place in the main block. It is blasted by the use of one auxiliary row of blast boreholes drilled along the front floor at a distance of 3 m from the edge of the floor. As the blasting of a block requires about 8 h, and the work on blasting is allowed by regulations only under daylight, therefore the blasting of auxiliary block has to be per formed in the II shift. The boreholes of the auxiliary block are drilled in the II shift in a great number along the front floor and protect by stoppers on material filling, and the blasting is performed after the completion of blasting on the main block and the return of excavator to work on it. Figure 4 presents the order of blasting the floor with excavation from the middle to the wings of floor.

7 SELECTION OF EXPLOSIVE TYPE

Determination the corresponding type of explosive for the given work environment is done through acoustic impedance, which means that the physical properties of the working environment and explosives by which the environment is to be blasted in the blasting process have to be brought into relationship, and this relationship is:

$$D_e * \gamma_e = K_o (V_o * \gamma)$$

where:

D_e- detonation velocity of explosive (m/s)

γ_e - the explosive density (kg/dm^3)

K_o - reflection coefficient

V_o - propagation speed of longitudinal waves through the working environment (m/s)

γ - volumetric mass of working environment being destroyed (for roof sediments 2,23 gr/cm^3).

In blasting, a particular attention should be paid to the seismic waves speed. Between the seismic wave speed Ct and the coefficient by Protodjakonov there is a certain dependence taking also into account the coefficient of fissure of the rock Kr as follows:

$$C_t = 1540\sqrt{\frac{f_r}{K_r}}$$

for sandstone

$$C_t = 1540\sqrt{\frac{1,88}{1,25}} = 1888,6\ m/s$$

Size of seismic wave speed indicates the application of possible obtaining technology (digging, tearing of soil or mining).
for marly limestone

$$C_t = 1540\sqrt{\frac{6,87}{1,25}} = 3610,3\ m/s$$

The reflection coefficient can be determined based on diagram (Figure 5). Since it is known that the works are carried out in soft and medium-hard rocks, in which the speed of propagation of longitudinal waves is up to 3600 m/s. Energy utilization of explosives in similar conditions is around 80%, and the rest is lost in the cracks and spent on seismic effect in mining. The reflection coefficient in this case according to Figure 5 has the value K_o= 0.5. Certainly, the values V_o and K_o can be exclusively determined experimentally measuring only at the first test blasting.

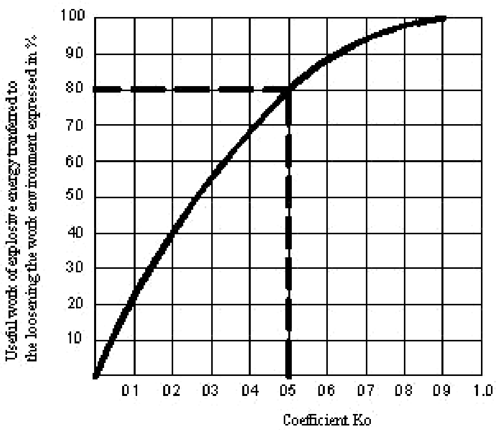

Figure 5 *Diagram for determining the value of K_o*

Based on the value of V_o and K_o, the appropriate type of explosive can be determined, as follows:

$D_e * \gamma_e = 0,5(3600 * 2,23)$

$D_e * \gamma_e = 4025$

"AMMONAL" explosive corresponds to this value of product density and detonation velocity of explosive. It can be concluded that this explosive is fully suitable for blasting at the open pit "Progorelica". The all other explosives of appropriate characteristics can be used for blasting, i.e. detonation velocity and density approximately equal to 4000.

8 SPECIFIC CONSUMPTION OF EXPLOSIVE

The possibility of obtaining rocks by blasting is characterized by a specific consumption of explosives, and it can be determined approximately according to the classification by Protodjakon:

$$q = 0,27\sqrt[3]{f}\ kg/m^3$$

for sandstone

$$q = 0,27\sqrt[3]{1,88} = 0,333\ kg/m^3$$

for limestone marl

$$q = 0,27\sqrt[3]{6,87} = 0,513\ kg/m^3$$

The ratio of blasting funnel radius (r) and the least resistance line (w) is called the indicator of explosion (blasting) effect.

$$n_g = \frac{r}{W}$$

For $n_g = \frac{r}{w} = 1$ funnel normal blasting is formed (swooping)

$n_g > 1$ - funnel of increased exploding is formed

$n_g < 0,75$ - no rebuff (swooping) but only the rock is loosened without formation of the funnel.

9 QUANTITY OF EXPLOSIVE PER METER OF THE BOREHOLE

The amount of explosive per meter of borehole and density depends on diameter of the borehole mine of explosive charge and is calculated using the formula:

$$q_b = \frac{\Pi \cdot D^2}{4} \cdot \rho \cdot p,\ \text{(kg/m)};$$

where:

q_b - quantity of explosive per linear meter of borehole (kg/m'),

D –borehole diameter (m),

ρ - density of explosive (kg/m^3),

p- coefficient of borehole filling,

$$p = \frac{d_1^2}{D^2}$$

d_1 –cartridge diameter

For available explosives, the quantity of explosives per meter of the borehole will be:

- For ammonal

p = (3.14 · (0.088^2)/4) · 1.05 · 0.63·10^3 = 4.02 kg/m'

Based on empirical data, knowing the amount of the proposed explosives, the cartridge diameter θ diameter 70 mm, which can fit in 1 m' of charging, it can be concluded that the real amount of explosive per meter of the borehole is:

p = 4.5 kg/m'

10 PLUG LENGTH OF THE BLAST BOREHOLE

The plug length of blast borehole influences the effects of blasting by increasing duration of explosive pulse, providing a complete detonation of explosive charge and prevents the uncontrolled spreading of rock mass. Experimental studies have shown that the length of mine plug largely depends on diameter of blast borehole and resistance in the floor of level. Length of the mine plug can be calculated depending on the length of the least resistance line: [2]

$l_p = (0.75 \div 1.0) * w$, (m)

$l_p = (0.75 \div 1.0) * 4 = (3 \div 4)$ m

the adopted length of plug is: $l_p = 4.0$ m

The inter-plugging will be performed only in the boreholes length L = 15 m and in the boreholes length of over 15 m.

11 CONNECTING AND ACTIVATION OF THE MINEFIELD

Connecting and activating the minefield will be carried out using:
- detonating cord,
- detonator no. 8,
- slowburning fuse,
- millisecond decelerators.

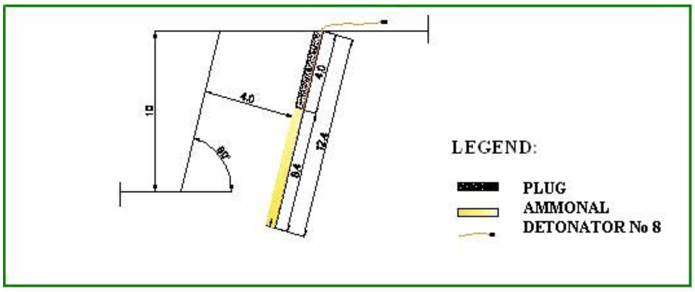

Figure 6 *Scheme of initiating explosive charges*

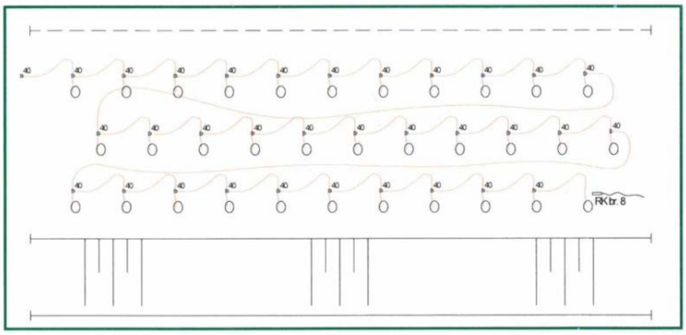

Figure 7 *Scheme of connection and activation the minefield*

CONCLUSION

In exploitation of mineral resources, it is necessary to fully comply with the parameters (quantity of explosive, deceleration intervals, minefield schemes, etc.) given in the design solution. Also, if for any reason there is a change of explosives or some other parameter of blasting, they should be thoroughly checked and subsequently analyzed.

During exploitation it is necessary to carry out continuous monitoring the results of blasting (quality of grinding, impact of blasting on the surrounding objects, etc.) for feedback analysis and possible correction of parameters that were unknown or taken into account during designing.

REFERENCES

[1] Technical Documentation of the Mine (in Serbian)

[2] Dr M. Perović; Workbook from Technology of Drilling and Blasting, 2007, Kosovska Mitrovica (in Serbian)